Lifelines and Livelihood: a Social Accounting Matrix Approach to Calamity Preparedness

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This paper[1] describes a Social Accounting Matrix (SAM)-based method for evaluating disaster preparedness and recovery strategies. The first section of the paper explains the overall approach and its extension to the evaluation of specific components of lifeline systems in a small Caribbean island. The next section explains the relationship between the physical and economic parameters of the energy-electricity-water lifelines and the tourism sector on the island and describes the construction of the corresponding accounting framework. The diachronic multipliers calculated from this extended matrix are used to determine the impact of potential hazards for tourism and other economic activities on the island. The case of a water storage tank, providing back-up supply to the major hotels, is used to illustrate the approach. In the final sections, the example is elaborated to highlight trade-offs between economic and non-economic costs for particular businesses or households. The events and strategies described then may be combined into an event-based scenario analysis.

Background — lifelines and social accounts

This paper describes a social accounting matrix-based approach to disaster preparedness and recovery planning suitable for small localities, such as islands, rural districts and inner city neighborhoods (NCEER, 1993). The rationale behind the project is essentially as follows. Natural disasters such as earthquakes, cyclones, floods, mud slides and volcanoes disrupt all sectors of an economy and all segments of a population (see NRC, 1989). Even when they are not impacted directly, individuals and businesses may be affected for an extended period through damage to lifelines such as water supply or roads, as well as through indirect effects such as the loss of livelihood or markets (Kreimer and Munasinghe, 1990; 1992; NEHRP, 1992).

A variety of techniques have been used to evaluate losses arising from disasters and the merits of alternative strategies for recovery. This includes input-output methods (Cochrane, 1975; 1992; Boisvert, 1992; West and Lenze, 1993), econometric models (Ellson, Milliman and Roberts, 1984; Guimares, Hefner and Woodward, 1992) and regression and time-series models (Freisema et al., 1979; Chang, 1983). Each approach has its advantages and limitations. The method used in this paper, a variety of input-output tables called a social accounting matrix (SAM), has the particular advantage that, given the requisite data, both the supply and the demand sides of the economy can be described in considerable detail. Input-output tables, in general, provide a means for representing the flows of goods, income and people between businesses, households and public service within an economy, or between neighboring localities and regions, providing a picture of how the different parts of a community are linked together as an productive technological and social network (NCEER, 1993). During a period of disaster, some of these flows are interrupted, with ramifications throughout the economy. With its intrinsic network structure, an input-output model allows the direct and indirect consequences of this damage for various actors in an area's economy to be represented and calculated. Although an input-output table strictly provides only a 'snap-shot' of an economy at a fixed point in time, this may be combined with various assumptions about economic behaviour in order to calculate the overall impacts of a particular event. These calculations may be rather straightforward, as with the conventional Leontief inverse method of solution, or adapted to dynamic analysis (Leontief, 1970), to computable general equilibrium (CGE) methods (Taylor, 1979; Brookshire and McKee, 1992), or to distributed lag methods (Ten Raa, 1986; Cole, 1988).

Disaster assessment models have usually

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been applied at the national or regional level, with some efforts at the county level (Rose and Benavides, 1993; West and Lenze, 1993). However, in the majority of cases, natural disasters have their most severe impacts on isolated localities and small or marginal communities. In the United States, for example, natural disasters are a national problem, experienced at the local level (Berke and Beatley, 1992). At this geographic scale, the details of both the supply and demand-sides of the economy can be quite idiosyncratic and specific — thus it may be necessary to take explicit account of particular businesses and populations, and the trade-offs between their competing interests. The SAM approach is useful here since households and the workforce are sub-divided by attributes such as occupation, education, income, gender and ethnicity. The use of SAM's in national, regional and local planning (Pyatt and Roe, 1977; Taylor, 1979) has been extended to small territories and islands (McCoy, 1990; Cole, 1992), villages (Adelman, Taylor and Vogel, 1988), sub-county (Robinson and Lahr, 1993) and inner-city neighborhoods (Cole, 1992). The present project extends their use to disaster planning.

The extreme severity of impacts to small localities and marginal populations often can be traced to poverty and inappropriate development, such as inferior infrastructure or housing. In some cases, victims are disadvantaged further by deficient recovery programs (Ebert, 1982; Cuny, 1983). In this sense, disasters may be viewed as failures of development (Jones, 1981; 1989). Thus, while the main priority must be to deal with the immediate consequences of the disaster (such as health and shelter), it is also necessary to devise an economic recovery which improves the quality of development so that hardship from future disasters will be reduced. The specific components of a sensible recovery strategy (such as improvements to lifelines, or other infrastructure) should also contribute to overall development. This is also true of planning instruments such as those described here. In particular, since most disasters occur with rather little specific warning (Jones and Tomazevic, 1981; Cuny, 1983), and small localities usually do not have the necessary planning capability, one need is for tools that can be constructed relatively quickly, so as to assess the economic damage caused by the disaster, but which then may be integrated into in the longer-term recovery and development process. Such techniques must be able to evaluate preparedness measures of various kinds, for example through cost-benefit type analyses of individual components of a strategy, as well as through investigation of more complex and integrated recovery and development strategies.

The various types of natural and human-made disasters, such as earthquakes, hurricanes and oil spills, have particular types of damage associated with them (Cuny, 1983). Despite this, the actual damage in each disaster varies considerably, depending, for example, on windspeed, location of epicentre, amount of flooding and on the condition of buildings and infrastructure, or the amount of pollutant. In effect, the damage arises from a set of specific events, or combinations of events, each of which may be considered separately, but which may be re-combined into an overall disaster and recovery scenario (NCEER, 1993). Activities aimed at damage mitigation, reconstruction, or recovery too may be considered on an event-by-event basis. Equally, a given type of event could be a component of several quite different disasters or recovery strategies. As part of this overall event-based approach, this paper extends previous work to consider specific components of lifeline systems and strategies connected with them. However, while this exercise focuses on a specific item, it is rehearsed in the context of a broad social and economic framework.

In general, the steps in such cost-benefit type calculations are as follows:

1 Identify the range of events and their probability of occurrence, or specify the actual events resulting from an event such as a hurricane or earthquake, or the hypothesized mitigation strategy;
2 for each event, identify the likely or actual direct losses (or gains) to all activities, including transactions with external actors;
3 estimate the indirect consequences on other production sectors, households and government;
4 check whether it is possible to reallocate resources so as to reduce the overall impact on various selected or community interests;
5 repeat 2 to 4 for all events; and
6 combine events according to the their assessed risk in order to assess the overall value of specific responses and lifeline.

The first items correspond to the steps suggested by, for example, French and Isaacson (1984). In the context of input-output analysis, step 3 is essentially the task of calculating the various multipliers and impacts as performed using the SAM. Step 4 may be improved or elaborated using a variety of scenario, programming and scheduling methods (Ray, 1984), while step 5 may be considered as an aspect of risk analysis (Van der Veen et al, 1994). This paper concentrates on items 3 and 6, focusing on a particular activity, as an illustration of the overall approach to developing and using the relevant sections of the model. Overall, the potential contribution of the methods adopted in this paper are that they extend the possibilities of constructing detailed input-output type models for small localities and for introducing fairly complex disaster and reconstruction scenarios, made up of many events, taking account of changes in the internal structure of the economy as well as the exogenous changes.

Economy and community in Aruba

The subject for the present study is the small Caribbean island of Aruba, until 1986 a member of the Netherlands Antilles. Aruba is some 20 miles long and in 1980 had a population of about 60 thousand. Aruba is less prone to natural disasters than most Caribbean islands. In early 1993 she experienced two minor earth tremors and most recently was a near miss for *Hurricane Brett* (which caused massive damage to favelas in nearby Caracas) and in 1991 suffered a fatal mudslide (Bon Dia Aruba, 1993). The island has a complex geology, lying 20 miles from Venezuela, across an extension of the Oca-Ancon fault (Doukhan and Leon, 1988). Although the island has not suffered a major natural disaster in recent years, Aruba has proved useful as a site for testing the model. This is because of the relatively good availability of data for the construction and testing of the SAM and the cooperation of the local authorities. Most importantly, in the mid-1980s, she experienced a dramatic economic upheaval following the shutdown of her major industry and the rapid expansion of the tourism industry. Over less than a decade, employment in Aruba first fell by over 30 per cent in 1985, and then rose to more than 30 per cent above its original level by 1990, leaving the island with a present population estimated at 75 thousand. In this period, the main 'driving force' of the island's economy shifted from oil refining (located in San Nicolas) to tourism (located in Oranjestad and Noord), which is now the life and livelihood of the island. This shift has changed the geographic, economic and demographic complexion of the community. This series of events afforded an opportunity to assess some details of the forecasts of the SAM model (NCEER, 1993), a significant step, since as West and Lenze (1993) observe, regional impact analysis and regional economic forecasting generally has been exempt from the necessary ex-post testing.

Aruba's history has been marked by a succession of disturbances. Until the present century, she experienced Spanish, Dutch and (very briefly) British rule, with gold and phosphate mining, small plantations and ranches with African and Indian slaves providing a largely subsistence livelihood, supplemented by migration to plantations around the Caribbean Basin during periods of intense drought. A large oil refinery was located on the island in the late-1920s, inducing massive immigration from around the Caribbean, the Americas, and eventually from around the world. This historic process, with populations arriving and departing with the fluctuating economic fortunes of the island, has led to a marked cultural division of labor in Aruba, so that today there are significant correlations between ethnic, sectoral, occupational, geographic and other divisions (Cole, 1993).

In the discussion that follows, households are sub-divided as urban and rural-Arubians, migrants and expatriates, in order to emphasize this last consideration. The native Arubian population is a tight-knit society with strong kinship relations that are relied upon in difficult times. As a generalization, there are distinctive lifestyle differences between the cosmopolitan urban and the traditional rural communities. Again, as a generalization, expatriates are typically wealthier with connections to major businesses, while migrants are typically poorer and socially marginalized and belong to Caribbean-wide social networks. For present purposes, the main point is that each community has distinctive resources and opportunities for dealing with crises, in the short and long-run. It is of note here that the Aruba Calamity Preparedness Committee has adopted a community based approach to disaster management.

The Aruba fuel-electricity-water network

The fuel-electricity-water system in Aruba is treated at the level of individual corporations and its principal customers. Oil is imported into Aruba by the Wickland trans-shipment terminal and a partially re-opened oil refinery operated by Coastal. Both are located in San Nicolas at the extreme East of the island on the site of the former LAGO refinery (subsidiary of Exxon). Fuel oil is piped from Coastal to WEB which is located at the middle-south of Aruba at Balashi. WEB co-produces electricity and water, the latter through distillation from sea water. Electricity and water are sold directly to Wickland and Coastal by WEB. Although in the past WEB provided electricity to LAGO, today WEB is contracted to purchase any excess from Coastal's own co-production facility (CEP, 1991). Electricity is distributed to other users by ELMAR, unlike the water which WEB distributes directly to residences, hotels and commercial users via separate pipelines. This distribution takes place through a series of partially linked regional networks. In addition to a group of water tanks at Balashi, each network is supported by one or more large storage tanks and water towers, including a large tank at the harbor in the capital Oranjestad. Recently, a new tank has been constructed at Alta Vista towards the western end of the island. This region of the island called Noord has seen very rapid commercial and residential development since the shut down of the LAGO refinery, and the trebling of the tourism sector. The principal purpose of the Alta Vista tank was to increase the pressure and provide more water to the rapidly expanding residential and commercial development. But, because of its proximity to the strip, the Alta Vista tank potentially serves as a back-up for the hotels should the primary mains supply, that runs along the Palm Beach via the Oranjestad tanks, fail.

In the past, there have been many problems with the water supply, and costly imports have been made through LAGO, and recently, Coastal (CEP, 1991). In one notorious incident, Exxon tankers were caught stealing water from the Hudson river, after washing their ballast just upstream on one of New York City's major drinking water inlets. Information about the robustness to failure of the present water supply system in Aruba has been provided by WEB in response to an interview and questionnaire. The main water production facilities were installed in 1983-1984 and 1989-1990 with a total capacity of 34,000 m^3 per day, with an average daily output of 20,250 m^3 in 1990. The six Balashi tanks hold about 60,000 m^3, which is roughly equal to all other tanks combined. The Alta Vista tank holds 12,500 m^3. Average daily consumption of water is 10,000 m^3 so if water production should fail completely the tanks hold approximately 6 days supply at regular usage rates. However, WEB estimates that this could be extended to 9 to 10 days with rationing. Water can be shipped in from overseas at a rate of 4000 m^3 per week (with a delay of about one week). In addition many of the older rural homesteads (cunucus) have their own small tanks, and ponds (or tankis) collect run-off from seasonal rainfall, which partially compensate for the somewhat lower tank capacities in some rural areas. The Santa Cruz area tanks, for example, provide only a 2-3 days supply. The five electricity generating steam turbines at WEB date from 1958 to 1964 and have an installed capacity of 114 MW. Because these generators were originally installed to provide power to LAGO, typically they run well below capacity (in 1990, average production was 35 MW with a peak production of 62 MW). In addition, there is a stand-by generator in case of emergency (CEP, 1991). While the electricity generating system appears to be more robust, the fuel supply lines could be damaged by floods during the hurricane season.

The Aruba tourism sector

Tourism in Aruba is expanding very rapidly and the island's livelihood is increasingly dependent on this sector. The industry comprises a range of hotels with an emphasis on high-rise and low-rise hotels, time-share apartments and a number of smaller condominium complexes. Income from tourism in 1990 was at least Afl 373 million (excluding time share) and hotel employment alone stood at 4,000 (out of a total labor force of around 27,000). It also involves a variety of shopping plazas, casinos (mostly linked to hotels) and other entertainment, eating and sightseeing facilities, providing another 3,000 jobs (CEP, 1991). From 1986-1989 the average annual growth rate of tourist arrivals in Aruba was 24 per cent, compared to 8.5 per cent in the Caribbean as a whole. Hotel capacity is expected to rise from 4000 in 1990 to 7,800 in 1994, compared to 2,400 in 1985 and 2100 in 1980.

While the hotels and tourist facilities themselves are vulnerable to direct damage from natural events, this is not the concern of the present paper. Rather, the concern is the secondary losses arising from a failure of the lifeline system supporting the sector. (The term secondary will be used here for these losses as opposed to other indirect losses in downstream activities to be calculated with the SAM). The financial impact on the hotel trade arising from a loss in water supply varies across hotels and depends on the type of tourist, how the matter is dealt with, and so on. Individual hotels have contingency plans (such as their own short-term back-up supply). Tourists in Aruba come mainly from North America for a 'relaxing week of sun, sand and sea' and tend to become very irritated by inconveniences (Spinrad, 1981). Problems result in early leavers, reimbursements, cancellations by next weeks visitors and non-returns the following year. Besides hotels, other tourist industries such as specialty shops, taxi-tours, restaurants, bars and casinos all loose business. Although the general character of these losses can be described, they are difficult to calculate in a mechanical fashion. The problem of imputing the economic secondary effects of a natural disaster on day-to-day business may be somewhat less tangible than assessing the reconstruction costs of damaged physical systems (French and Keown, 1993). The appropriate way to accumulate information is through interviews with hotels managers and others involved in the trade. Again this would be on an hotel-by-hotel basis for the major hotels, and a sample basis for smaller business (similar to Tierney, 1993), and case studies of actual disasters (such as those in Guam, St Croix or south Dade county, Florida).

The Aruba lifeline-tourism SAM

The Aruba lifeline-tourism SAM comprises three components:

1 The core of the Arubian economy and the 'rest-of-the-world' economy, including social distribution across categories of household;
2 the lifeline sectors comprising the oil trans-shipment terminal, the (re-opened but much smaller) oil refinery, the electricity and water production at WEB and the electricity distribution activities of ELMAR; and
3 the tourism sector comprising high- and low-rise hotels, casinos, bars, tourist shops, taxi-and tours, as well as demand from stay-over and cruise-ship visitors.

The combined SAM is shown in Table 1(a). Each entry in the table represents a transaction — the amount paid by one actor (business, sector or household) to another over the course of a year. For example, the Afl 67 million of fuel oil purchased by WEB from the oil refinery appears in the top-left part of the matrix. The columns show the expenditures by each actor, and the rows show their purchases. Total income and expenditures for each actor are approximately equal.

The core economy

The core 1990 matrix was constructed by scaling the previously constructed 1979 Aruba SAM (Cole et al, 1983; NCEER, 1993). The scaling uses multi-proportional RAS procedure that allows new data to be added to the original matrix in a fashion which minimizes the information loss from the original matrix. The overall level of activity was constrained to match a set of national income and production accounts (NIPA) which were first constructed using a variety of data from the Central Bank of Aruba, the World Bank, IMF and the Aruba Development Plan (1990) and the Aruba Capital Expenditure Plan (CEP, 1991). These national income and product accounts first were organized into a small matrix (in a manner similar to that described by Hanson and Robinson, 1989). Additional information on value added and wages by sector, imports and exports, and public sector activity were then used to scale individual activities and transactions to 1990 levels. These procedures are discussed in detail in NCEER (1993). The supply-side of the economy is sub-divided into the main (1-digit) sectors. The demand side into four classes of household, government, investment, and overseas trade and finance activities. Households are sub-divided as urban and rural Arubians, and expatriates and migrants, each with distinctive income and expenditure patterns. It is this last feature which qualifies the table as a social accounting matrix.

The lifeline network

The lifeline network has been constructed mainly from company reports for WEB and ELMAR, data in the Capital Expenditure Program (CEP, 1991) and the information provided by WEB. The various transactions referred to earlier have been included although a number of inconsistencies between the accounts remain unresolved. An effort has been made to allocate co-production costs within WEB between water and electricity, with WEB treated as a vertically integrated corporation producing its own intermediate inputs. This is necessary because of the differences in the potential impacts. For example, a loss in electricity production affects water production far more than the reverse.

The tourism sector

The data for the tourism network also comes from a number of sources. The gross data on tourism revenues comes from the Central Bank of Aruba (1990) and CEP (1991). Details of the allocation of tourist and hotel expenditures between activities comes from Spinrad (1981), Latham (1984) and more recent publications of the Aruba Tourism Board. There is some secrecy with respect to details of the industry (not least, the casino sector). However, the data in the SAM offer a fair impression of the island's tourist industry, and in addition, the

Table 1: Aruba Social Accounts with Tourism and Lifeline Sectors

(a) Social accounts[1]

		Lifelines					Tourist activities						Other production					Local factors					Households institutions							Capital tourists & overseas						
		Wick	Coas	WEB	WEBE	LMA	Tran	High	LowR	Tour	Bars	Casi	Taxi	Indu	Cons	Othe	Othe	Labo	Labo	Labo	Depr	Loca	Rura	Urba	Migr	Expa	Firm	Gove	Hou	Firm	Gov	Stay	Crui	Impo	Over
Sector or activity		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
Wickland Termina	1																																	2023	
Coastal Refinery	2			67																														2000	
WEB-Electric	3	1	2		44	50				0						2																			
WEB-Water	4	1	3			1		4	2	0	1	1		1		3	1						6	25	1	4		1							
ELMAR	5	2						8	4	2	0	3		2		8	4						9	34	2	6		1				4			
Transport-Telecon	6																																		
HighRise Hotels	8	1	1	0						2				0	1		23						0	1	0	0				14		158			
LowRise Hotels	8				2					1													0	1	0	0						119			
Tourist Shops	9																						10	35	5	6						43	8		
Bars/Cafes	10																						1	3	0	0						23	1		
Casino	11																						1	1	0	0						74			
Taxi/Tours	12							0	0			0																				20	2		
Industry/Agricultu	13	2	4	4		2		0	1	1	0	0		18	30	1	25						57	138	14	24		6		67	22	9		26	
Construction	14	3	8	2		1		0		0				6	0	0	14						1	6	0	1		1	48	211	9				
Other Commerce	15	2	2	3		1		1	1		0	0	5	31	16		14						102	257	26	45		3		8	2			224	
Other Services	16	1	3	2		1		14	14	3	2	4		26	23	20	58							11		2		9			5	107		279	
Labor (low edu)		1	2	1	2	1		13	9	3	1	5	1	5	40	23	25							11		2		9				14			
Labor (middle edu)	18	2	4	2	2	1		15	10	5	1	5	1	4	43	34	46											40				5			
Labor (high edu)	19	3	7	4	3	4		8	5	3	1	2	1	3	31	19	93											88							
Depreciation	20	5	13	4		10				1		31	1	14	9	6	84											1							
Local Surplus	21			9		15		23	12	19	7		5	62	10	128	331																		
Rural Households	22																	88	49	10		55		15				22							3
Urban Household	23																	41	122	207		350						50							14
Migrant Household	24																	22	12	3		19				12									3
Expatriate House	25																	7	22	37		95						3							10
Firms	26																				142	92													
Government	27							14	11	3			7	39	5	19		10	15	20	15		1	16	0	8	117								
Household Capita	28																						−6	68	−2	16									
Firms Capital	29																										120								297
Government Capit	30																											−3							42
Stayover Tourists	31																																		672
Cruise Ships	32																																		11
Imports	33	1997	2017					65	50	70	14	21		236	100	468	100	468	60																
Overseas Finance	34							34	5			4											11	47	13	25		9	50	118		97		640	
Expenditures		2022	2066	100	53	88		200	123	112	28	76	22	445	309	732	757	168	220	276	157	613	247	805	72	177	237	298	95	416	38	672	10	5094	1051
Receipts		2023	2068	100	53	89		200	123	114	28	76	33	451	310	743	764	168	220	276	159	622	242	785	71	173	237	299	76	417	38	672	11	5098	1053

(b) Marginal impacts

Wick Coas WEB WEBELMA Tran High LowR Tour Bars Casi Taxi Indu Cons Othe Othe Labo Labo Labo Depr Loca Rura Urba Migr Expa Firm Gove Hou Firm Gove

Sub-totals	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
All Lifelines	1.0	1.0	1.8	2.5	2.1	1.0	0.3	0.2	0.1	0.2	0.2	0.2	0.1	0.2	0.1	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.3	0.2	0.3	0.2	0.3	0.1	0.1	0.1
WEB-Water	0.0	0.0	0.0	1.0	0.0		0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Tourism Sector	0.0	0.0	0.0	0.1	0.1		1.1	1.1	1.1	1.1	1.1	1.1	0.0	0.1	0.0	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.0	0.1	0.0
All Other Sectors	0.0	0.0	0.5	0.7	0.9		0.8	0.9	0.6	0.8	1.0	2.5	2.8	2.1	1.5	2.4	1.5	1.5	1.5	1.3	1.4	1.6	1.5	1.4	1.3	1.3	1.6	0.7	1.0	1.4
Wages	0.0	0.0	0.2	0.4	0.4		0.4	0.5	0.3	0.3	0.5	0.6	0.2	0.6	0.3	0.6	1.3	1.4	1.4	0.6	0.4	0.3	0.3	0.3	0.3	0.5	0.8	0.2	0.3	0.3
Margins	0.0	0.0	0.2	0.3	0.5		0.3	0.4	0.3	0.5	0.3	0.6	0.3	0.3	0.3	0.8	0.4	0.4	0.4	0.3	1.4	0.4	0.4	0.4	0.3	0.3	0.5	0.1	0.2	0.3
All Households	0.0	0.0	0.4	0.6	0.8		0.7	0.8	0.6	0.7	0.8	1.3	0.6	0.9	0.8	1.3	1.7	1.7	1.7	1.0	1.6	1.7	1.7	1.6	1.7	0.9	1.5	0.3	0.4	0.5
Rural	0.0	0.0	0.1	0.1	0.1		0.1	0.2	0.1	0.1	0.2	0.2	0.1	0.2	0.1	0.2	0.7	0.4	0.2	0.2	2	1.1	0.1	0.1	0.1	0.2	0.3	0.1	0.1	0.1
Urban	0.0	0.0	0.3	0.4	0.5		0.5	0.5	0.4	0.5	0.5	0.8	0.4	0.5	0.3	0.8	0.7	1.0	1.2	0.8	1.0	0.4	1.4	0.4	0.4	0.6	1.0	0.2	0.3	0.3
Local Value Adde	0.0	0.0	0.5	0.7	1.0		0.8	0.9	0.6	0.8	1.2	1.4	0.7	1.0	0.6	1.5	1.8	1.8	1.8	2.0	1.8	0.8	0.8	0.7	0.7	0.9	1.4	0.3	0.5	0.8
Government	0.0	0.0	0.1	0.1	0.2		0.2	0.2	0.1	0.1	0.4	0.5	0.2	0.2	0.1	0.3	0.2	0.2	0.3	0.7	0.2	0.2	0.2	0.1	0.2	0.6	1.2	0.1	0.1	0.1

Notes:

1. Data are from various sources and years. The matrix has been scaled and balanced (see text). Amounts are shown to nearest AFl (1990).
2. Total impacts per unit exogenous change in demand calculated to a 5 year time horizon (see text).

available data allow some individual hotels to be described in the matrix, in a similar fashion to WEB and ELMAR in the lifelines sector. The present division into high and low-rise hotels follows a survey by Spinrad (1981) that differentiates between the class of hotel (high-rise tending to be larger and more luxurious). It also has relevance for their vulnerability to natural disasters, directly and indirectly, since high rise hotels are often more susceptible to hurricane damage, earthquakes and fires, and the two classes of hotels are concentrated at opposite ends of the tourist strip. Thus, breaking down the data in this way, allows the impacts of events on individual parts of the industry, or different events, to be assessed.

Impact assessment using the SAM

The SAM shown in Table 1(a) is a snapshot of the Arubian economy in 1990. Multipliers and impact coefficients calculated from the table may be used to estimate the impact of a change to the economy following a disaster, at a variety of levels of sophistication.

In most cases, the first step is to calculate a set of 'standard impacts' for the economy — that is, the increase in the level of every activity as a result of a unit (say, one Afl) increase in demand for every other activity. This calculation is carried out by 'inverting' the matrix of coefficients obtained from Table 1(a) to obtain a variety of multipliers and total impact coefficients. Table 1(b) shows the impact of unit exogenous shifts in demand on each activity on combinations of activities — lifelines, tourism, other industry, households and government. The table shows, for example, that when indirect and downstream effects are accounted for, a one Afl loss in receipts by high rise hotels leads to an income loss of 2.1 Afl for all production activities (30, 110, and 80 cents from the lifeline, tourism, and other industry sectors respectively), a 67 cent loss to combined households, of which 11 cents and 60 cents go to rural and urban Arubians respectively, and a 19 cent fall in revenues to government.

Multipliers are the ratio of the total economy-wide impact of changes in the level of a given activity, to the original impact. The total impact coefficients shown are the ratio between the level in a given activity (say, household income) arising from a unit change in another activity (such as the level of tourism). Both may be calculated in several ways; most common are Type I or Type II multipliers (Miller and Blair, 1985; Stevens and Lahr, 1988). There are a number of limitations on the use of these multipliers; in particular, the use of fixed technical coefficients, insufficient attention to price effects, comparative static analysis, and so on. There are several techniques for compensating for such limitations whilst attempting to retain the relative simplicity of the input-output method (Miller and Blair, 1985). A comparison of actual and forecast shifts in employment and income in Aruba over the years 1980 to 1990 suggested that a time-lagged method is likely to give better results (Cole, 1988; NCEER, 1993). Diachronic multipliers and impacts are calculated for all the activities in the SAM with impacts calculated up to a prescribed time horizon using average or marginal coefficients. The multipliers shown in Table 1(b) are calculated up to a five-year time horizon. The calculation may be modified to account for continuous technical change or appropriate discount rates for each activity. Similar considerations also apply when using the results of impact analysis in cost benefit analysis, particularly the question of how to deal with trade-offs between economic and non-economic welfare and the competing needs of interest groups and communities (Laylard, 1980).

A schematic example

Small societies, like Aruba, have a relatively uncomplicated configuration of sectorial and lifeline links, but despite this they have subtle and often contradictory social and economic objectives (to the point that actors may say whether a solution is acceptable, but not why). In this situation, it is obviously important to discuss a range of alternative events, responses and scenarios with different groups within society so as to elicit critical trade-offs and choices, and negotiate compromises. The purpose of the example considered next is partly to confirm existing data in the SAM, but also to reveal the response mechanisms that are implicit in the parameters of any cost-benefit analysis, and are required for a more complete assessment of various events and strategies.

For both purposes it was found useful to begin with the simple calculation that is summarized in Table 2; a serious rupture to the main pipeline from Oranjestad to the Palm Beach, cutting the strip off from the Balashi plant and the Harbor tanks and cutting off the normal water supply to the hotels for as much as five days while repairs are made. It could arise through several causes; a hurricane, an oil spill, an aircraft crash or an earthquake. As a response to this event, the Alta Vista tank is assumed to become the fall-back supply for the hotels. The 'value' of the tank for this

Table 2: Tourism-Lifeline Event Example

Typical Event	Assume a rupture of the main pipeline from Balashi water works and Harbor tanks to Palm Beach hotel strip.	
Determine	Impact on Tourism Revenues and Downstream Income with, and without, the Alta Vista water tank.	
Direct Loss to Tourism Industry	Early leavers/reimbursements -	3–4 capacity days lost
	Cancellations (same year) -	1–2 capacity days lost
	Non-returns	2 capacity days
	TOTAL	7 capacity days (about 2 per cent of annual tourist income)
	Annual tourist income (1990)	Afl 706 million
	Potential loss from rupture	Afl 14 million (US$8 million)
Total Loss	Tourism Multiplier	Approx. 2.1 (see text)
	Direct and Indirect Loss	Approx. Afl 30 million (excluding repairs)
Chance of this Event	Probability over 10 year horizon	say 1–5 per cent
Potential Risk	Likely loss over 10 year horizon	about Afl 0.3 to Afl 1.5 million
	Typical discount horizons	3 to 20 years
	Discounted potential loss	about Afl 0.1 to Afl 0.5 million
Cost of Water Tank	Construction cost	Afl 1.96 million.
Justified Expenditure	Not justified on the basis of this event alone. However, Alta Vista tank has other uses and there are several other contingencies covered by the tank.	

purpose is to be assessed by asking how much damage to the tourism trade is avoided because of this particular use of the Alta Vista tank (noting here that this was not the primary intended purpose for this tank). This event has been hypothesized by the Calamity Preparedness Committee and is taken as typical of the kind of disaster with which we are concerned. It has been used as a basis for discussion with representatives of the Calamity Committee, the tourist industry (AHATA, the Aruba Hotel and Tourism Authority), WEB (the Water and Electric Company) and with several government departments.

In this example, it was assumed that a given loss of water supply to the hotels would lead to a 3 to 4 capacity-day immediate loss in business to this sector as visitors cut short their vacation. In addition, there would be an estimated 1 to 2 capacity-day loss through cancellations (because of uncertainty as to whether the problem will be solved) and a 2 to 3 day capacity-day loss because of non-returning tourists in following years, giving a total of around 7 capacity-days. Thus, should this event occur, the island would lose a total of about Afl 14 million in tourism receipts, since the industry is worth about Afl 700 million annually to the island. Taking a tourist sector multiplier of about two (see above), the total (direct and indirect loss) would be around Afl 28 million. Fortunately, the likelihood of such a disaster is fairly small. Assuming that the probability over a ten year period of damage of this magnitude is from 1 to 5 per cent, the potential risk (cost of event times the potential loss) would be from Afl 0.3 to 1.5 million. Since the Alta Vista tank cost Afl 1.96 million to install in 1990, its construction would not be justified by this event alone. Moreover, private sector discount horizons in the tourism sector in Aruba are especially short and appear to range between three and six years (compared to twenty to thirty years for the public infrastructure supporting it). Florin-for-florin, for example, income lost from next years' non-returning visitors is worth less than income lost from early-leavers. Discounting the estimate to present value is likely to cut this estimate in half. However, the scenario is only one of many such possibilities with varying probabilities of occurrence, and these should be combined to present an overall potential loss.

Responses and welfare criteria

The implied welfare objective of reducing losses to Aruba's tourism business is only one of several possible goals and may not be the most appropriate for the island as a whole, let alone that of specific communities. But, whatever the goal, there may be ways of reducing the social and economic cost for some or all of the island's community by reallocating the reserves in the Alta Vista tank. This possibility is now explored using the full detail of the social accounting matrix, and suppositions about the response of the island's economy and community to shortfalls in income and water supply. The basic question being asked here is, if the island loses five days of water, how might the cutbacks be distributed in order to minimize the ensuing impacts to selected interests?

For purposes of comparison, we begin by calculating the impacts of an economy-wide six day loss of water supply. The loss of income to activities resulting from this uniform cutback are shown in column (a) of Table 3. In this case, the loss in income is distributed more or less proportionately across all activities; tourism, private sector, households and government. The income lost by the tourism sector is Afl 6.8 million, Afl 44.5 million is lost to local business and Afl 23.4 million by all households. These amounts depend upon the multipliers and cross-impacts for the various sectors. However, this calculation, and those that follow, are subject to several other considerations, now discussed, particularly how costs and trade-offs vary over time and across interests.

The importance of having continuous water supply lifelines varies across businesses (Tierney, 1993). Because of the vulnerability of water supply in Aruba, and its criticality to their own needs, some businesses have their own small reserve supplies usually lasting a few days. Thus, an allocated loss of so many days mains supply implies a smaller net loss. Restaurants and hotels will be impacted more rapidly than taxi services or telecommunications, for example. For most production activities, a loss of a few days supply will not lead to a pro-rated loss in output since it is usually possible to stretch reduced supplies. The total economic impact on each activity will be determined by the short-term (direct) curtailment of its activities, plus the subsequent indirect loss from other sectors. A poultry farm, for example, may suffer a short-term loss in output (including loss of livestock), followed by decline in orders from hotels and the tourism sector because of early departures by tourists. But, after a few days without water some businesses will be obliged to shut-down temporarily, until service is restored, or suffer cancellations and loss of future business. If the business closes altogether, the potential loss will depend on the economic and human capital of the business, rather than its day-to-day running costs.

For households, the economic costs are almost entirely indirect, arising from loss of wage and entrepreneurial income. Nevertheless, there is direct hardship (non-economic costs) arising from loss of water supply, the disutility of which will eventually exceed that from loss of income. In the very short-run, minimum needs would come from other sources: for example, potable water can be purchased in shops, or waste water used for gardens. But few households, despite the prevalence of water reservoirs in some areas, could be totally without water for a week, even with major usage curtailed. Although supply may always be restored at a cost, the temporary nature of supply cutbacks and the resulting uncertainty makes this a matter of increasing irritation.

Such considerations imply that there is a non-linear relationship between the loss of water supply and the impact on activities, and also on employee income, purchase of inter-

Table 3: Impacts of Uniform and Programmed Allocations

Criteria	*(a) Uniform allocat* Schedule	loss afim	*(b) Favor tourism secotr* Weight	sched.	loss afim	*(c) Favor local economy* Weigh	sched.	loss afim	*(d) Favor all household* Weight	sched.	loss afim	*(e) Favor rural household* Weight	sched.	loss afim	*(f) Weighted interests* Weight	sched.	loss afim
Water loss (constraint)	151381			151381													
All lifelines	5.0	53.4		2.2	21.1		1.9	20.2		2.2	22.7		2.2	24.1		2.2	22.1
Tourism sector	5.0	6.8	1	0.6	0.2		1.6	0.8		1.7	1.6		1.7	2.4	2	1.8	1.3
All other sectors	5.0	44.5		1.1	4.9	1	0.3	1.5		3.4	24.2		3.5	40.9	1	2.2	15.2
Wages		11.8			1.1			0.6			4.4			8.5			3.0
Margins		12.1			1.3			0.5			5.5			11.1			3.5
All households	5.0	23.4		6.3	2.2		6.3	1.1	1	5.1	9.6		5.5	18.7		5.7	6.3
Rural	5.0	4.3		7.0	0.4		7.0	0.2		5.7	1.7	1	4.2	3.2	2	4.9	1.2
Urban	5.0	14.7		6.0	1.4		6.0	0.7		6.0	6.1		6.0	23.0	1	6.0	4.0
Local value added		26.7			2.6			1.4			11.0			21.8			7.3
Government	5.0	6.5		0.1	0.5		0.1	0.3		0.1	2.5		0.1	4.3		0.1	1.5
Objective	None		Minimize income loss			Minimize income loss			Minimize weighted welfare loss			Minimize weighted welfare loss			Minimize weighted welfare loss		

Notes: Some criteria and welfare items are mutually exclusive. Schedules are averaged by groups of activities mediate goods, household responses and so on. These may be dealt with in a number of ways, most straightforwardly as fixed limits on the number of days that an activity could be without water, before reaching a crisis point, taking into account its own reserves and temporary supplies. These limits stand as surrogates for a variety of the more extreme consequences arising from the event — bankruptcy, illness or death and so on. For the following calculations, the maximum loss of supply is shortest for lifeline and livelihood activities and the hotel sector (2 to 4 days). For most other business activities, the limit is taken to be 5 to 6 days, while for households it is taken to be 6 to 7 days. For some purposes, however, it also is useful to adopt a more explicit trade-off between economic and non-economic components of welfare loss.

Re-allocation of supply to reduce welfare loss

The results of the uniform five-day schedule now are used as a basis for comparison with four programmed responses in which different activities receive favorable treatment, subject to fixed constraints and competing welfare criteria. In addition to those just mentioned, a general constraint on these reallocations is that the *total* loss of supply by volume is the same as with the five-day uniform loss, noting here that the water company WEB applies price differentials by size of business, rental value of homes, amount used, as well as guaranteed supplies or special concessions to some major businesses, including some hotels.

Column (b) in Table 3 shows the revised schedule when cutbacks are designed to minimize the loss of income to the tourist industry. Such a schedule might be adopted in order to protect the interests represented by AHATA. Comparing (b) with (a) shows that this processes reduces the economic impact on all activities greatly. Loss of welfare to businesses is measured as lost income and, in this case, the impact on hotels is almost eliminated, reduced from Afl 23.4 million to Afl 0.2 million. In general, schedules favoring a particular production sector tend to reduce supply to activities with least income loss per unit of water supply. Since households do not generate income, the maximum allowed cutback in supply is passed to households. The outstanding loss is placed successively on activities with higher water utilization, up to the level of the various constraints. All sectors, including the favored sector, tourism, lose some income through indirect effects and will share in the direct cutbacks if this is required to satisfy the overall volume constraint. This pattern is seen also when the schedule favors business activities in the local economy, shown in the third column (c) of Table 3. The principle change is a shift of financial loss from the local sector to the tourism sector. This shift in priorities might arise for example if the Aruba Chamber of Commerce, which represents local small businesses, could persuade the government that their interests should hold sway over those of AHATA and household interests.

The likelihood in Aruba of a swift reaction, in the media or through Aruba's effective patriarchal political system, might ensure that households would not be treated so arbitrarily. Thus, in contrast to the above, columns (d) to (e) in Table 3 show the result of calculations which favor households. In this case, it is assumed that the welfare loss to households is a trade-off between the loss of household income from employment and entrepreneurship and the irritation at losing water supply for an extended period and the non-economic loss. This is assumed to increase increasingly rapidly as the shortfall in supply is extended and, for purposes of calculation, is assumed to result in household malfunction that can be measured as a proportion of annual income. When all households are favored equally, as in column (d), the schedule tends to push the burden back onto businesses, although the net loss in supply to households is still greater than with uniform allocation. The important trade-off here is between the economic and the social cost — basically, how many days pass before the non-economic loss exceeds the economic loss? The shorter this period, the greater will be the cutbacks forced onto the business sector and the greater will be the loss of income to both businesses and households. When rural households are favored, as in column (e), the schedule tends to push the burden onto other households, and onto the local sector. In this example, some restoration of water supply is preferred at the expense of income. When the schedule favors urban households, the pattern between households becomes similar to case (c), reflecting the dependence of these households on entrepreneurial income from the local economy. Compared to the simple calculation shown in Table 2, these results suggest that particular components of the lifeline system might be used in a more cost-effective way.

Combining events and weighing interests

In the above examples, specific trade-offs have determined the schedule appropriate to particular interests. These interests also may be weighted to establish some broadly acceptable allocation, recognizing that there are several difficulties in balancing economic and non-economic utilities across competing interest groups. The simplest, and most common method is to weigh economic losses to the various interest groups uniformly; for example, by minimizing the loss to domestic value added, or that part of value added that is retained on the island. But if this is done subject to constraints, such as upper limits based on industry and other assessments, then it is evident that non-economic factors are implicitly included. This is equally the case when the future income expectations of the various actors are discounted to their present values at different rates. Thus, even this approach, as a variant of contingent valuation (Haneman, 1995), should be considered to be a multi-criteria (MCA) in the sense of Van der Veen et al (1994), rather than a cost-benefit analysis. In any case, as indicated above, the marginal costs to particular interests may be considered paramount, or deserving of greater weight. In this case, the re-scheduling of supply might necessitate weighing the various interests accordingly. Column (f) of Table 3, for example, illustrates the result of a hypothetical negotiation about how the various interests in Aruba might be traded off. In general, these are difficult issues to address, but reviewing trade-offs in the manner indicated earlier, may reveal preferences that are difficult to ascertain by other means. What matters here is that the final outcomes proposed can be understood by the various parties, and are acceptable to them. Once such trade-offs have been ascertained for several events, or negotiated across interest groups, the same mix of trade-offs can be adapted to determine their response to other events, which also may be reviewed through specific examples such as that shown in Table 2.

As emphasized in the introduction, disasters comprise a series of events and a given event might be assessed in the context of many disaster scenarios. Thus, an interruption in water supply in Aruba might come from a variety of contingencies — hurricanes, oil spills, mechanical breakdowns, all to be mitigated by the Alta Vista tank and other strategies. As long as consistency is maintained between the trade-offs and constraints, then the approach above may be extended to create a composite scenario, resulting from many actual failures and responses to them. To determine the risk value of a strategy, or a specific component of it, sets of events, each with a specified probability, must be combined together to provide an aggregate potential cost. There are here again a number of considerations, such as the treatment of non-additive cumulative effects, when events reinforce each other to create an especially critical situation (for example, simultaneous damage to components of the supply system) or the assessment of risk for large events, of unknowable uncertainty, that go beyond the scope of the present paper.

In conclusion, it is emphasized that whether any particular response to a disaster is viable depends on technical, economic, political and social considerations. For example, the calculations in this paper suggest a number of ways of dealing with a breakdown in water supply in Aruba through re-allocation of water supply, but this possibility depends on the physical arrangement of mains pipelines, storage tanks and valves. Similarly, while the calculations suggest that major economic loss might be avoided if the burden of water shortage was passed to households, the viability of this would depend on the island's ability to organize emergency supplies for households. The non-economic hardship depends on the balance of essential, versus discretionary, water usage by households and the possibilities for assuring a minimum supply. The prevalence of many household reservoirs in rural areas in Aruba, for instance, suggests these could be used for emergency supplies in rural areas, but this, in turn, would only be effective if it took account of the social networks on the island and the degree of access provided to different communities. Calculations, such as those presented here, can provide information on outcomes that might be used to negotiate a mutually acceptable compromise for contested resources. Thus, although the approach taken in this paper has considered a specific example, this is to be set against the wider considerations for the management of natural disaster preparedness and relief strategies.

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References

Adelman, I., Taylor, S. and Vogel, S. (1988), 'Life in a Mexican Village: A SAM Perspective', *Journal of Development Studies*, Volume 25, Number 1, pp 5–24.

Berke, P. and Beatley, T. (1992), *Planning for*

Earthquakes: Risk, Politics and Policy, Johns Hopkins University Press, Baltimore.
Boisvert, R. (1992), 'Direct and Indirect Economic Losses from Lifeline Damage', in *Indirect Consequences of a Catastrophic Earthquake*, National Earthquake Hazards Reduction Program, FEMA, Washington, pp. 207–266.
Bon Dia Aruba (1993), *Trembelo di Aruba*, Press Report, January.
Brookshire, D. and McKee M. (1992), 'Indirect Loss Measurement and Computable General Equilibrium', in *Indirect Consequences of a Catastrophic Earthquake*, National Earthquake Hazards Reduction Program, FEMA, Washington, pp. 267–324.
Central Bank of Aruba (1990), *Annual Report*, Oranjestad.
CEP (1991), *Capital Expenditure Plan 1991–1995*, Department of Economic Affairs, Oranjestad.
Chang, S. (1983), 'Do Disaster Areas Benefit from Disasters?', *Growth and Change*, Volume 15, pp. 24–31.
Cochrane, H. (1975), *Natural Hazards and their Distributive Effects*, Monograph Number 3, Institute of Behavioral Studies, University of Colorado.
Cochrane, H. (1992), 'Overview of Economic Research on Earthquake Consequences', in *Forum on Consequences of a Catastrophic Earthquake*, National Research Council, Washington.
Cole, S. (1988), 'The Delayed Impacts of Plant Closures in a Reformulated Leontief Model', *Proceedings of the Regional Science Association*, Volume 65, pp. 135–149.
Cole, S. (1992), 'A Lagrangian Derivation of a General Multi-proportional Scaling Algorithm', *Regional Science and Urban Economics*, Volume 22, pp. 291–97.
Cole, S. (1993), 'Cultural Accounting for Small Economies', *Regional Studies*, Volume 27, Number 2, pp. 121–136.
Cole, S., Opdam, H., Van Veen, B., and Zambrano, R. (1983), 'A Social Accounting Matrix for Aruba', Mimeo, Instituut voor Toegepast Economisch Onderzoek (Department of Economic Development), Oranjestad, Aruba.
Cuny, F. (1983), *Disasters and Development*, Oxford University Press, Oxford.
Doukhan, P. and Leon, J. (1988), 'Parametric Methods for Evaluating Seismic Disturbance', *Revista Tecnica Intevep*, Volume 8, Number 1, pp. 13–22.
Ebert, C. (1982), 'Consequences of Disasters for Developing Nations', *Impact of Science on Society*, Volume 32, Number 1, pp. 93–100.
Ellson, R., Milliman, J. and Roberts, R. (1984), 'Measuring the Regional Economic Effects of Earthquakes and Earthquake Predictions', *Journal of Regional Science*, Volume 24, pp. 561–579.
Freisema, H., Caporaso, J., Goldstein, G., Lineberry, R. and McCleary, R. (1979), *Aftermath: Communities after Natural Disasters*, Sage, Beverly Hills.
French, S. and Isaacson, M. (1984), 'Applying Earthquake Risk Analysis Techniques to Land Use Planning', *Journal of the American Planning Association*, Volume 50, Number 2, pp. 509–522.
French, S. and Keown, S. (1993), 'Earthquake Risk Analysis', in Klosterman, R., Brail, R. and Bessard, R. (eds.), *Spreadsheet Models for Urban and Regional Analysis*, Rutgers University Press, New Brunswick, pp. 271–286.
Guimares, P., Hefner, F. and Woodward, D. (1992), 'Wealth and Income Effects of Natural Disasters: an Econometric Analysis of Hurricane Hugo', *Review of Regional Studies*, Volume 22, pp. 49–54.
Hanemann, W. (1995), 'Are Markets the Solution? Improving Environmental Policy', *Contemporary Economic Policy*, Volume 13, Number 1, January, pp. 74–79.
Hanson, K. and Robinson, S. (1989), *Data, Linkages, and Models*, US Department of Agriculture, Washington.
Jones, B. (1981), *Planning for Reconstruction of Earthquake-stricken Communities*, Peoples Republic of China-United States Joint Workshop, Beijing.
Jones, B. (1989), 'The Need for a Dynamic Approach to Planning for Reconstruction after Earthquakes', *Mimeo*, National Center for Southgate Engineering Research (NCEER 93-0002), Suny, Buffalo.
Jones, B. and Tomazevic, M. (1981), *Social and Economic Aspects of Earthquakes*, National Science Foundation/Yugoslav Board of Scientific and Technological Cooperation, Bled.
Kreimer, A. and Munasinghe, M. (Eds.) (1990), *Managing Natural Disasters and the Environment*, World Bank, Washington.
Kreimer, A. and Munasinghe, M. (1992), *Environmental Management and Urban Vulnerability*, World Bank, Washington.
Latham, E. (1984), *Direct and Indirect Impacts of Tourism on the Population of Aruba*, Tourism Department, Oranjestad.
Laylard, R. (1980), *Cost Benefit Analysis*, Penguin Modern Economics Readings, London.
Leontief, W. (1970), 'The Dynamic Inverse', in Carter A. and Brody A. (Eds.), *Contributions to Input-Output Analysis*, North-Holland, Amsterdam, pp. 17–46.
McCoy, J. (1990), 'Bauxite Processing and Employment: A Case Study of Jamaica', *Social and Economic Studies*, Volume 39, Number 2, pp. 1–47.
Miller, R. and Blair, P. (1985), *Input-Output Analysis: Foundations and Extensions*, Prentice Hall, New Jersey.
National Earthquake Hazard Reduction Program (NEHRP), (1992), *Indirect Consequences of a Catastrophic Earthquake*, FEMA, Washington.
National Research Council (NRC), (1989), *Estimating Losses from Future Earthquakes*, National Academy Press, Washington.
NCEER (1993), *Social Accounting For Disaster Preparedness and Recovery Planning*, National Center for Earthquake Engineering Research (NCEER 93-0002), SUNY, Buffalo.
Pyatt, G. and Roe, A. (1977), *Social Accounting Matrices for Development Planning with Special Reference to Sri Lanka*, Cambridge University Press, London and World Bank, Washington.
Ray, A. (1984), *Cost-Benefit Analysis: Issues and Methodologies*, World Bank, Washington.
Robinson, M. and Lahr, M. (1993), *A Guide to Sub-*

County Input-Output Modeling, Regional Science Association International, Houston.
Rose, A. and Benavides, J. (1993), *Inter-industry Models for Analyzing the Economic Impacts of Earthquakes and Recovery Policies*, Department of Mineral Economics, Pennsylvania State University.
Spinrad, B. (1981), *The Aruba Tourism Plan*, DECO, Oranjestad.
Stevens, B. and Lahr, M. (1988), 'Regional Economic Multipliers: Definition, Measurement and Application', *Economic Development Quarterly*, Volume 2, Number 1, pp. 88–96.
Taylor, L. (1979), *Models for Development Planning*, MIT Press, Cambridge.
Ten Raa T. (1986), 'Dynamic Input-output Analysis with Distributed Activities', *Review of Economic Statistics*, Volume 68, pp. 300–310.
Tierney, K. (1993), *Urban Seismic Risk Assessment*, Disaster Research Center, University of Delaware.
van der Veen, A., Green, C., Pflugner, W., and Wierstra, E. (1994), 'Appraisal Methods as Tools in Evaluating Responses to Long Term Climatic Changes: Cost Benefit Analysis and Multi-Criteria Analysis', *Journal of Coastal Engineering* (forthcoming).
West, C. and Lenze, D. (1993), *Modeling Natural Disaster and Recovery: An Impact Assessment of Regional Data and Impact Methodology in the Context of Hurricane Andrew*, Bureau of Business and Economic Research, Gainsville, University of Florida.